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Modeling in Regional Power Systems – Central America

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Electricity Infrastructure, PNNL

The International Smart Grid Action Network Workshop, Brookhaven National Laboratory, April 14-15, 2016

U.S. DEPARTMENT OF STATE

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U.S. DEPARTMENT OF ENERGY

PNNL's work for Bureau of Energy Resources, U.S. Department of State

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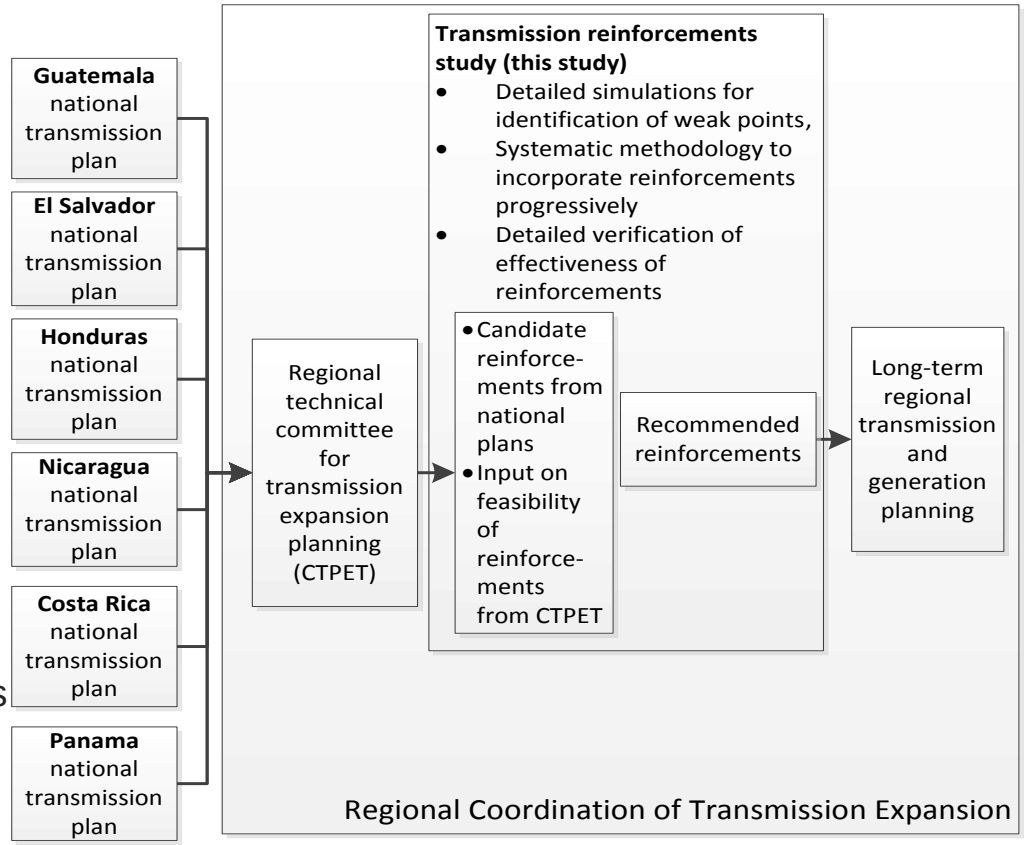
- The U.S. Department of State, Bureau of Energy Resources, Power Sector Program (PSP), under the auspices of the Connecting the Americas 2022 initiative, provides technical and regulatory support to the Central American regional electricity market
- Under the U.S. Department of State's PSP program, PNNL have delivered technical and analytic support to Ente Operador Regional (EOR, the Central American regional system operator) and the government of Honduras
- Topics of technical and analytic support:
  - Regional (6 countries) transmission reinforcement
  - Renewable integration (Honduras and currently for the full region)
  - Extra-regional electricity trade
  - Stability analysis of the regional system
- This presentation overviews these activities from the point of view of the role of modeling

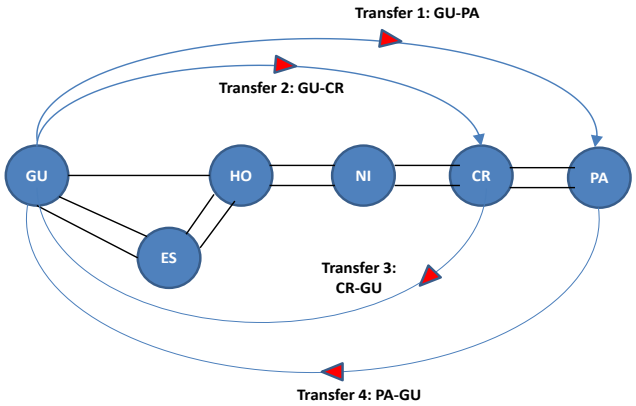
Central America Regional Market

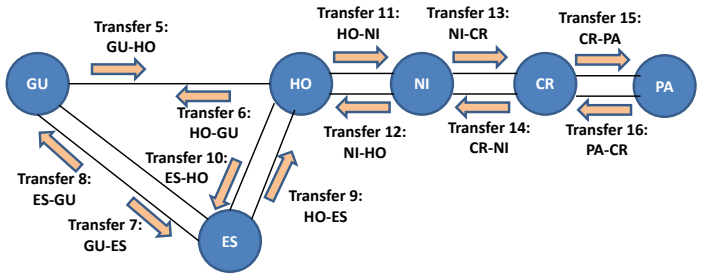
- Regional institutions
  - Regional System Operator –EOR– (Ente Operador Regional)
  - Regulatory commission –CRIE– (Comision Regional de Interconexion Electrica)
  - Transmission Owner –EPR– (Empresa Propietaria de la Red)
- National institutions (6 countries):
  - National market operators and national system operators
  - National regulators
  - National transmission companies

Transmission Reinforcements in the Central American Regional Power System

- Recommend short- to mid-term transmission reinforcements to achieve 300 MW transfer capacity between any pair of MER member countries. Related study objectives were as follows:
  - Identify weak points in the transmission network, with respect to regional reliability performance criteria.
  - Propose network reinforcements.
  - Verify that reinforcements meet regional reliability performance criteria.
  - Discuss proposed reinforcements with EOR and regional working groups.
  - Estimate the cost of reinforcements (this is part of separate work).







Collaboration

- Regional institutions in Central America and national system operators have developed great coordination and collaboration mechanisms that allows them to operate the Regional Electricity Market and the Regional Electrical System
- US Department of State's PSP coordinates needs with regional institutions: EOR, CRIE, and others
- Under US Department of State's PSP, PNNL performs detailed technical analysis in close collaboration with region's technical staff from:
  - EOR
  - Regional technical committees in transmission planning and operational security
  - Individual national operators

Conclusions

- Central America has progressed in integrating their national power systems after several years of efforts
- There are processes in place to share information to build models and coordinate operation and planning
- Under the U.S. Department of State's PSP program, PNNL has been able to support progress of regional system through detailed technical analysis and modeling to bring clarity to key topics

Thank you

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GridLAB-D: Smart Grid Simulation and Microgrids

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Electricity Infrastructure group, PNNL

The International Smart Grid Action Network Workshop, Brookhaven National Laboratory, April 14-15, 2016

GridLAB-D: A Unique Tool to Design the Smart Grid

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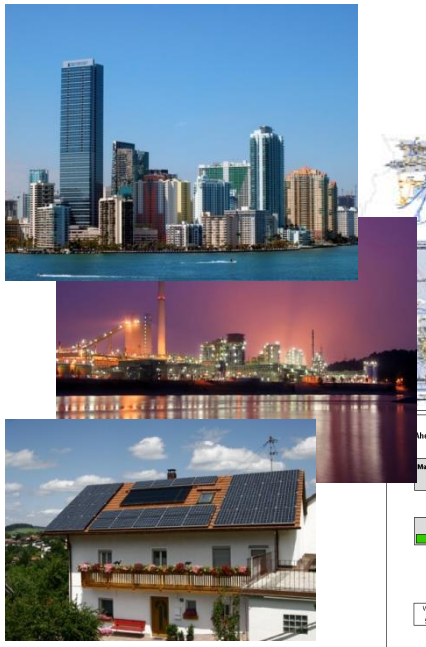
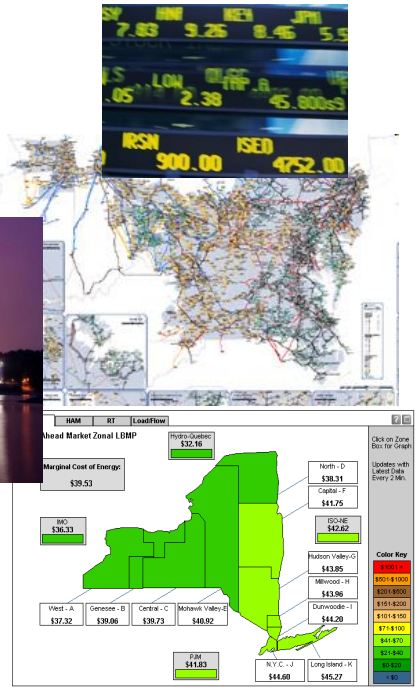
Unifies models of the key elements of a smart grid:

Power Systems ***Loads*** ***Markets***



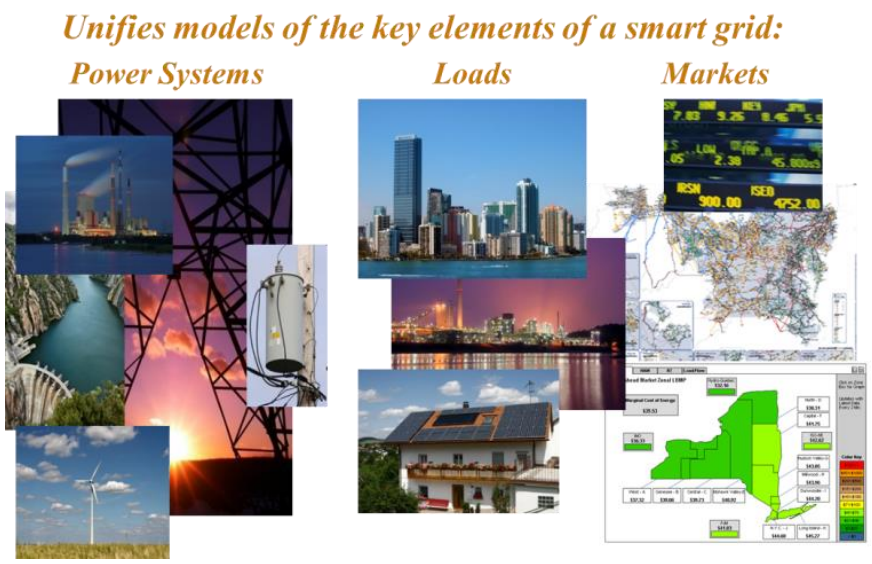


Over 55,000 downloads in over 150 countries

- ✓ Smart grid analyses
  - field projects
  - technologies
  - control strategies
  - cost/benefits
- ✓ Time scale: sec. to years
- ✓ Open source
- ✓ Contributions from
  - government
  - industry
  - academia
- ✓ Vendors can add or extract own modules

- Open-source, time-series simulation of an operating smart grid, from the substation to individual end-use loads & distributed energy resources, in unprecedented detail
- Simultaneously solves 1) power flow, 2) end-use load behavior in tens of thousands of buildings and devices, 3) retail markets, and 4) control systems

GridLAB-D Capabilities



- Performs time-series simulations
  - Seasonal effects (days to years)
  - Midterm dynamic behavior (secs to hrs)
  - Machine, line and transformers dynamics (milliseconds)
- Simulates control system interactions
  - Device- and system-level controls
  - Market interactions

Typical Use Cases

- Interconnection of distributed generation and storage
- New and innovative retail market structures (e.g., DSOs)
- Evaluation of demand response and energy efficiency
- Volt-VAr optimization and conservation voltage reduction design
- Sectionalizing, reconfiguration, automation, and restoration
- Microgrids and resiliency

PNNL Volt-VAr Optimization (VVO) and Conservation Voltage Reduction (CVR) Work

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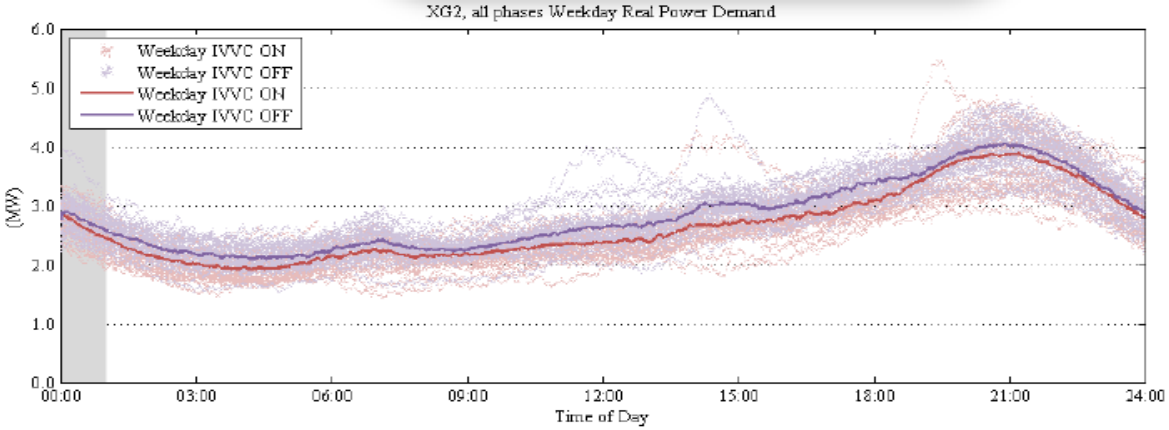
- Initial work with AEP
  - Modeled a commercial VVO system in GridLAB-D on 8 AEP distribution feeders
  - Performed field evaluation of VVO on 8 feeders to validate GridLAB-D model and verify system performance

Volt-VAr Optimization

Validating and improving the performance of control systems

- Initial work with DOE
  - Initial CVR paper cited 400+ times (2010)
  - Follow-on report examined VVO as part of the SGIG grant projects (2011)



- Follow on work with Industry
  - Conducted field evaluations of VVO for industry as an impartial 3rd party evaluator
  - Developed a VVO evaluation method that improved on existing methods
  - Developed an on-line VVO evaluation method in partnership with AEP (patented pending)

Microgrids as a Black Start Resource

Microgrids as a Black Start Resource

- Microgrids generally do not have the capacity to actively participate in the restoration of the transmission system.
- Microgrids with sufficient generation can support restoration by providing black-start support to larger generating units.
  - Power for condensate and feed pumps
  - Power for air handlers
- This could involve energizing large potions of de-energized lines to reach the generation unit(s). This may include sub-transmission lines and their transformers.
- The current work is focusing on the in-rush and reactive power absorption associated with charging larger transformers and high voltage lines.
- This type of procedure would need to be directed by the utility as part of a larger restoration plan.

Three-Phase Unbalanced Dynamics

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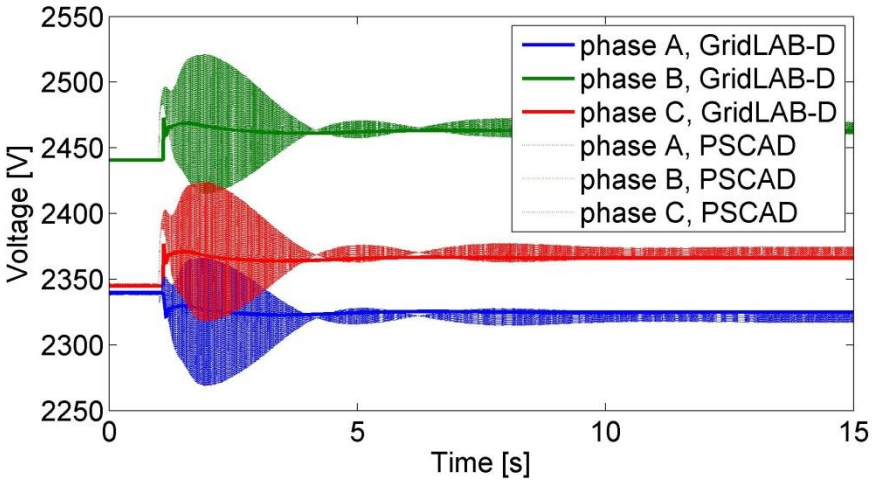
Current Use

- Developed to examine the dynamic characteristics of feeder-size microgrids.
- Allows for the proper sizing of generator assets.



Other Potential Uses

- Develop new control algorithms.
- Model ancillary services at the microgrid/distribution level.
- Understand the impact of substantial amounts of single-phase distributed resources.
- Understand the impact of renewable generation.

Transformer and Cable Inrush

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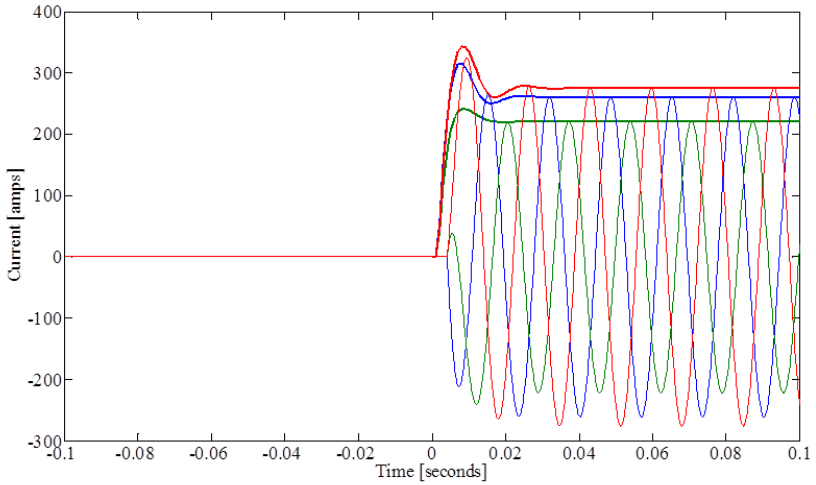
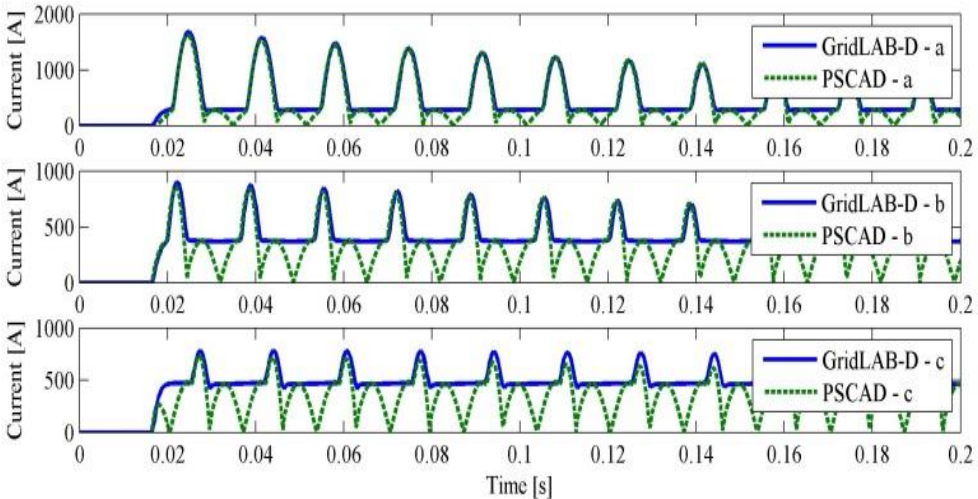
Current Use

- Developed to examine constraints on switching operations.
- Allows for the shortest possible restoration time, without overloading equipment or initiating protective actions.



Other Potential Uses

- Quantify the lifetime impact on equipment due to energizations.
- Evaluate the impact on protection coordination.
- Improve restoration and switching operations.



Open-Source Model Drives Collaboration

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- Open-source model encourages utilization, industry transformation
  - New capabilities introduced by vendors, utilities, other national labs (PNNL manages and validates)
  - EPRI's [Open]DSS declared open source
  - Utilities starting to buy-in, direct use & consultant-based
  - Spurring vendor capabilities
- Encourage integration with other tools
  - Co-simulation via FNCS (an open-source PNNL tool) - communications, buildings, transmission, wholesale
- Collaborative development projects with multiple national labs
  - ORNL, NREL, SNL, LBNL, ANL
- Currently used by at least 9 national labs, dozens of utilities, many universities

Collaboration

Encouraging collaboration through transparency

NREL
Sandia National Laboratories
OAK RIDGE National Laboratory
Argonne NATIONAL LABORATORY
INL Idaho National Laboratory
Pacific Northwest NATIONAL LABORATORY
Lawrence Berkeley National Laboratory
NIST National Institute of Standards and Technology U.S. Department of Commerce
Lawrence Livermore National Laboratory

GridLAB-D: A Unique Tool to Design the Smart Grid

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- Thank you

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The Community Keeps Growing …

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National Rural Electric Cooperative Association
A Touchstone Energy® Cooperative

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

Ausarid

ALSTOM

Battelle
The Business of Innovation

NRECA CRN COOPERATIVE RESEARCH NETWORK

nationalgrid

SIEMENS

GE Energy

AEP AMERICAN ELECTRIC POWER

PG&E Pacific Gas and Electric Company®

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OPEX Systems
Enabling Operational Excellence

SAP

MILSOFT Utility Solutions

Pacific Northwest NATIONAL LABORATORY

EnerNex CORPORATION

NREL

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

UNIVERSITY OF WASHINGTON 1861

UCIrvine

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Lawrence Berkeley National Laboratory

NIST National Institute of Standards and Technology U.S. Department of Commerce

CORNELL UNIVERSITY FOUNDED A.D. 1865

PURDUE UNIVERSITY

IOWA STATE

UNM

Cal

WSU WICHITA STATE UNIVERSITY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Sandia National Laboratories

Colorado State University

VirginiaTech

OAK RIDGE National Laboratory

Lawrence Livermore National Laboratory

CEPRI 中国电力科学研究院 CHINA ELECTRIC POWER RESEARCH INSTITUTE

University of Victoria

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

STANFORD UNIVERSITY

Solar Integration and Mitigation Strategies

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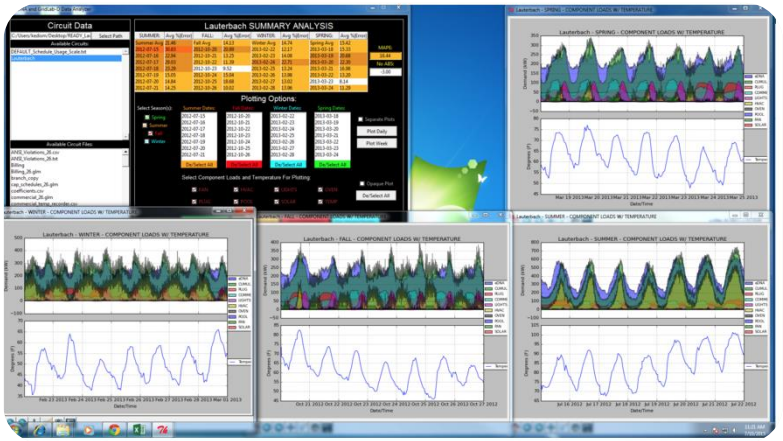
- Solar/inverter models validated in partnership with NREL
  - Incorporates weather data
  - Define-able smart inverter controls
- Developing a user-friendly, cloud-based tool to speed up PV integration (w/ SCE, Qado)
  - Utilities can quickly asses new integration requests and identify circuit issues
    - Voltage flicker and rise, overloads, power factor
  - Utilities can evaluate mitigation deployment strategies to increase penetration levels in an economically efficient manner
    - DR, DS, smart inverters, traditional upgrades
- Transitioning to practice
  - Development under California Solar Initiative with co-funding from DOE-OE
  - Qado Energy (small business) is developing front end and workflow to deploy to other utilities
  - However, much of the development is open-source

Solar Integration

Helping utilities to speed-up interconnection and adoption



Evaluation of SGIG Grants – Potential Impacts of Primary Technologies

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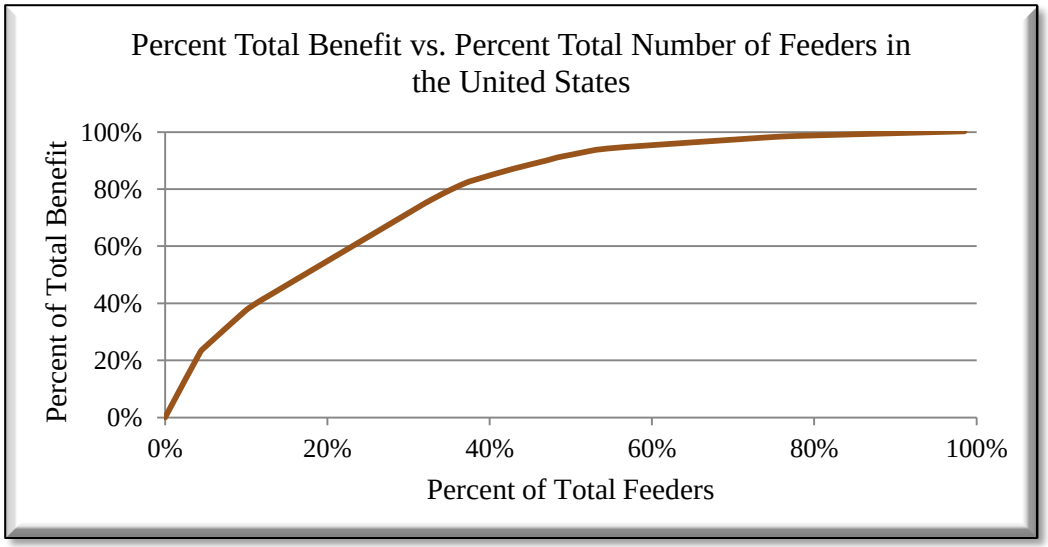
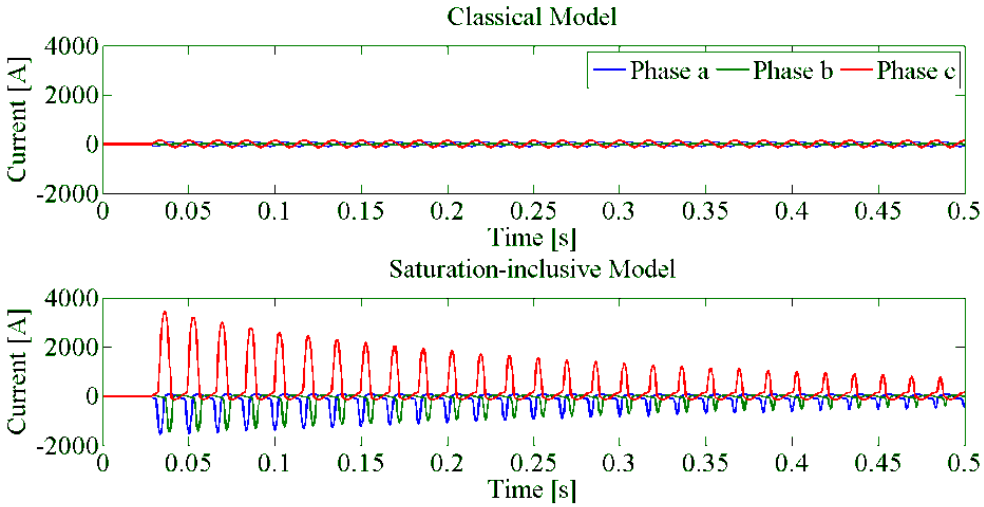
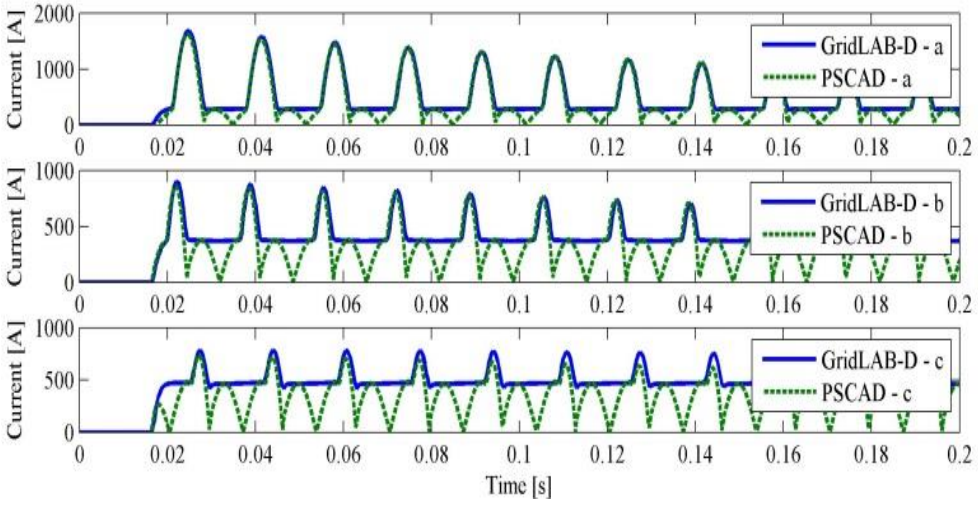
- Distribution automation benefits
  - Volt-VAR optimization (annual energy saved) 2% – 4%
  - Reclosers & sectionalizers (SAIDI improved) 2% – 70%
  - Distribution & outage management systems (SAIDI improved) 7% – 17%
  - Fault detection, identification, & restoration (SAIDI improved) 21% – 77%
- Demand response
  - Instantaneous load reductions 25% – 50%
  - Sustainable (e.g. 6-hour) load reductions 15% – 20%
- Thermal storage (commercial buildings)
  - Peak load reduction @ 10% penetration: up to 5%
- Residential photovoltaic generation
  - 3-5 kW each, 0% – 6% penetration (0.1% - 3% annual energy saved)
  - Low penetration: losses generally decreased
  - High penetrations, deployed in an uncoordinated manner, can increase system losses



Transformer Saturation Effects

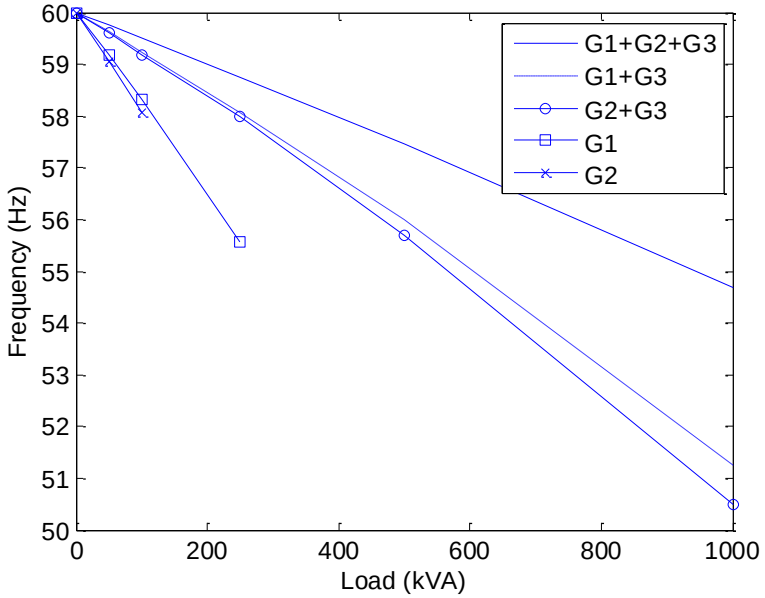
- The current transformer in-rush models do not account for saturation.
- The saturation effects is critical to determine the impact on protective relaying.
- This effect is currently being incorporated.





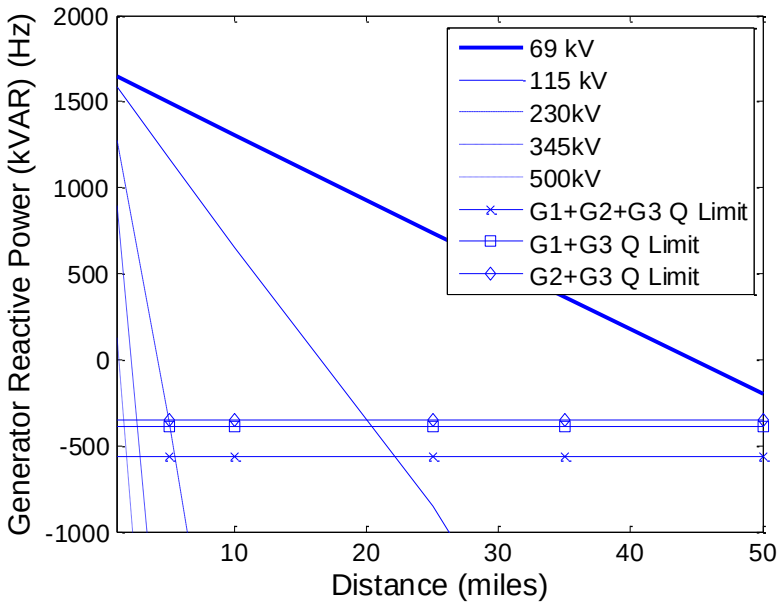
Operational Nomograms (Frequency)

- The nomogram to the right contains the frequency information for the WSU microgrid.
- The nomogram contains the results from numerous simulations.
  - Different generator configurations
  - Different peak load levels
- The use of the nomogram would change if there are soft start devices, or other generation resources.



Operational Nomograms (Reactive Power)

- The nomogram to the right contains the reactive power absorption information for the WSU microgrid.
- The nomogram contains the results from numerous simulations.
  - Different generator configurations
  - Different transmission voltage levels
- The use of the nomogram would change if there were local shunt inductors or FACTS devices.



Conclusions from Nomograms

- For the WSU microgrid:
  - It might be possible to start a 50 MW coal power plant
  - 115 KV is the highest voltage
  - 50 miles is the longest distance
  - Shunt capacitors and/or FACTS devices could increase the distance/voltage level